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ScienceDirect
Renewable and Sustainable Energy Reviews
12 (2008) 1176–1186
RENEWABLE & SUSTAINABLE ENERGY REVIEWS
www.elsevier.com/locate/rser

Analysis of biodiesel promotion in Taiwan

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Received 6 November 2006; accepted 5 January 2007

Abstract

Biodiesel is one kind of biodegradable fuel. Substituting fossil diesel with biodiesel can reduce air emissions, increase the domestic energy supply, and create new markets for farmers. Further, generating biodiesel from energy crops cultivated on polluted farmlands can provide a solution for re-using polluted farmlands.

This paper investigates the characteristics and benefits of biodiesel and its current status and development potential in Taiwan, identifies barriers to the adoption of biodiesel, and formulates key policy measures to achieve the target (i.e., 100 million liters per year by 2010 and 150 million liters by 2020) of the 2nd National Energy Conference.

The results of this study show that the potential annual output of biodiesel can amount to 233–285 million liters, meaning that the goal of the second National Energy Conference could be achieved. However, there are many barriers to the practical adoption of biodiesel. Many issues (such as acquiring material sources, establishing a recycling system, defining economic and legal measures, and improving public acceptance and inter-ministry coordination mechanisms) must still be addressed to actively promote biodiesel utilization.

Keywords: Biodiesel; Policy measures; National Energy Conference

Contents

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1364-0321/$ - see front matter
doi:10.1016/j.rser.2007.01.009

1. Introduction

Developing renewable energy has become an important worldwide energy policy to reduce greenhouse gases caused by fossil fuel. The Taiwanese government, among other governments, is paying close attention to this issue. The First National Energy Conference was convened in 1998 to promote the utilization of new and clean energy sources in Taiwan. Developing biodiesel was one of the planned projects of that meeting. In June 2005, Taiwan held the second National Energy Conference and decided to increase the contribution of biodiesel to 100 million liters per year by 2010 and 150 million liters by 2020 [1].

According to the "Renewable Energy Development Act (Draft)", biomass energies are those generated by directly utilizing or indirectly processing plant materials, methane, common wastes, and industrial wastes [2]. Biodiesel can be generated by chemical or biochemical processes from various types of biomass including vegetable oils, animal fats, and waste edible oil. The physical properties of biodiesel are similar to fossil diesel, and biodiesel can be used directly or blended with fossil diesel. Using biodiesel in a diesel engine can reduce emissions of sulfur oxides (SO_x), total hydrocarbons (THC), polycyclic aromatic hydrocarbons (PAHs), particulate matter (PM), and carbon monoxide (CO). However, nitrogen oxides (NO_x) emissions might increase due to better combustion.

The development and promotion of biodiesel in Taiwan is in the initial stage. To achieve the goal of the second National Energy Conference, it is necessary to assess the development potential of biodiesel in Taiwan and identify possible barriers hampering its development. This paper investigates the characteristics and benefits of biodiesel and its current status and development potential in Taiwan, identifies barriers to the adoption of

biodiesel, and formulates key policy measures to achieve the target of the second National Energy Conference.

2. Characteristics and benefits of biodiesel

2.1. Biodiesel characteristics

Biodiesel is an alternative fuel consisting of fatty acid alkyl esters. Biodiesel can be generated by chemical or biochemical processes from various types of biomass including vegetable oils, animal fats, and waste edible oil [3]. Transesterification is the primary biodiesel conversion process in Taiwan, and its reaction scheme is depicted in Fig. 1 [4]. Furthermore, the biochemical processes are gradually developing in Taiwan.

Biodiesel is relatively safe for use in diesel engines and storage in diesel container due to its high flash point. Biodiesel can be used alone as fuel, or mixed with fossil diesel in diesel engines without major adjustments. An engine using biodiesel has fuel consumption, torsion, and traction ratio similar to that of fossil diesel. Biodiesel offers similar performance and engine durability as fossil diesel [5], and there is no limitation on the mixing ratio of biodiesel and fossil diesel. However, the mixing ratio will affect power output to some extent. A frequently-seen mixture is 20% of biodiesel blended with 80% of fossil diesel (B-20). Biodiesel actually has better lubricating qualities than fossil diesel, and this can prolong engine life and reduce the need for maintenance [5]. It is estimated that a biodiesel blend of just 1% could increase lubrication by as much as 65% [6].

2.2. Biodiesel benefits

Biodiesel utilization has considerable environmental advantages. Biodiesel contains more oxygen molecules that facilitate complete combustion; the use of biodiesel can reduce the generation of free carbon, decreasing black smoke generated from fossil diesel. From a whole life-cycle viewpoint (including cultivation, production of oil, and conversion to biodiesel), biodiesel has a small net contribution to carbon dioxide (CO_2), which is one of the major greenhouse gases. Due to its extremely low sulfur content, emissions of sulfur oxides from biodiesel are much lower than from fossil diesel. Other pollutants, such as CO, THC, PM, SO_x, and PAHs, are significantly reduced (Table 1) [7–9]. However, since the composition of biodiesel contains more oxygen, its better combustion might cause reactions with nitrogen in the air, resulting in more nitrogen oxides. This problem can be relieved mainly by using exhaust after-treatment system, the selective catalytic reduction system (SCR) or by delaying the angle of ignition [10]. In summary, biodiesel is an

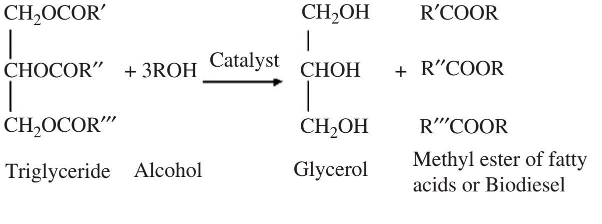


Fig. 1. Transesterification of triglyceride with alcohol [4].

Table 1
Average emissions of biodiesel compared to fossil diesel [7–9]

Emission type	B-100	B-20
Total hydrocarbons (THC) (%)	−80 to −90	−20 to −30
Carbon monoxide (CO) (%)	−30 to −40	−10 to −20
Particulate matter (PM) (%)	−30 to −50	−5 to −15
Nitrogen oxide (NO_x) (%)	+4 to +12	+2 to +4
Polycyclic aromatic hydrocarbons (PAHs) (%)	−51 to −75	−13 to −60

Note: "+" means the emissions of biodiesel increase compared to fossil diesel; "−" means the emissions of biodiesel decrease compared to fossil diesel.

environment-protective energy, and developing biodiesel will help realize the development targets of renewable energy and secure sustainable development in Taiwan.

3. Status of biodiesel in Taiwan

Taiwan is a densely populated island with limited natural resources. Due to rapid economic growth and a subsequent increase in energy consumption, Taiwan's greenhouse gas emissions are also increasing. Due to lack of self-sufficient energy resources, Taiwan relies on imports for the majority of its energy. Therefore, exploiting indigenous energy (e.g., biodiesel) is becoming more and more critical.

In the First National Energy Conference (1998), the Taiwanese government decided to seek new clean energies, and biodiesel development was listed as one of the planned programs. In 2001, the government promulgated the "Administrative Regulations on the Production and Sales of Renewable Energies Such as Ethanol, Biodiesel, or Oil from Recycled Waste". These administrative regulations listed ethanol, biodiesel, or oil recycled from waste under the scope of application of the "Petroleum Administration Act". To promote the utilization of biodiesel, Article 38 of the "Petroleum Administration Act" explicitly prescribes that producers of renewable energies are exempted from the petroleum stockpiling obligations and petroleum fund payments [11].

The Energy and Environment Research Laboratories (EERL) of the Industrial Technology Research Institute (ITRI) associated with the American Soybean Association (ASA) and the Taipei City Council conducted the diesel engine performance and emissions measurement of garbage trucks using 100% and 20% of soy-based biodiesel in 2001. In October 2004, EERL cooperated with Taiwan NJC Corporation to establish Taiwan's first biodiesel demonstration system in Chiayi with an annual output of approximately 3000metric tons. The system uses primarily waste edible oil as feedstock to produce biodiesel through a transesterification process. This is a milestone in biodiesel promotion in Taiwan [4].

Further, the Environmental Protection Administration (EPA) launched the "Biodiesel Road-Test Program" in garbage trucks in response to the renewable energy development policy of the Executive Yuan. The EPA has provided subsidies on purchasing biodiesel since 2004, with total subsidies of NT$ 100 million (US$ 3 million) per year. More than 900 garbage trucks have been joined in the program using between B-10 (10% of biodiesel blended with 90% of fossil diesel) and B-100 biodiesel. This program has helped 13 counties and cities across the nation to collectively consume about 1300 thousand liters of

biodiesel between 2004 and 2005. Road-test results indicate that biodiesel is effective in improving air quality [12].

In 2005, the Council of Agriculture (COA) selected 90 ha of fallow farmland on which to try planting three kinds of energy crops (i.e., sunflowers, rape, and soybeans) as raw materials for producing biodiesel [13]. Since 2006, the COA has subsidized farmers planting energy crops on 2000 ha of fallow farmland, and established a biodiesel production system (subsidy: NT$ 60,000/ha (US$ 1800/ha) including NT$ 45,000 (US$ 1350/ha) of fallow allowance already provided). It is estimated that the area will expand to 8000 ha by 2007.

In addition, more than 200 ha farmlands in Changhua have been polluted by h eavy metal (e.g., cadmium) over the past decade. The Changhua County Government actively promotes biomass cultivation in its efforts to re-use cadmium-contaminated farmlands. According to experiments and valuations of polluted farmlands made by Environmental Protection Bureau of Changhua County, to encourage farmers planting soybeans indicates higher feasibility. The Taiwan NJC Corporation cooperating with farmers to produce biodiesel can stabilize farmers' income, effectively re-use contaminated farmlands, and develop renewable energy. Experimental planting has been done according to four different pollution levels in 2006. Successful experimental planting in the next year will provide a solution for re-using polluted farmlands.

4. Development potential of biodiesel in Taiwan

Raw materials for biodiesel production include vegetable oil (e.g., rapeseed oil, soybean oil, etc.), animal fats, and waste edible oil. European biodiesel is primarily produced from rapeseed oil, soybeans are used in the United States, and in Japan waste edible oil is used.

Fig. 2 shows Taiwan's potential annual output of biodiesel. The consumption of edible oil (including animal and vegetable oil) in Taiwan is about 780 thousand metric tons per year [14]. According to the experiential recovery data of waste edible oil in Japan (i.e., 20%) [15], 156,000 metric tons of waste edible oil could be recycled in Taiwan each year. Considering other competing uses (e.g., feed, saponification, etc.) and the actual recycling rate, the potential annual output of waste edible oil as a raw material for biodiesel is about 78,000 metric tons. Waste edible oil can be transformed into approximately 90% biodiesel and 10% glycerol, and since 1000 liters of biodiesel is equivalent to approximately 0.88 metric tons of biodiesel, the annual output of biodiesel generated from waste edible oil could reach approximately 80 million liters.

According to the conclusions of the second National Energy Conference, the target of biodiesel promotion is 100 million liters per year by 2010 and 150 million liters by 2020. To achieve the target of 100 million liters, cultivating energy crops or importing raw materials to produce biodiesel has to be considered. According to the data provided by the Council of Agriculture, Taiwan has about 260,000 ha of fallow farmland (double cropped) and 240,000 ha of idle farmland (single cropped) [16]. Taiwan's commitment to the World Trade Organization (WTO) to open the agricultural products market will increase the area of fallow farmland. Among the energy crops best suited for cultivation in Taiwan, sunflower has an oil output of about 600 kg/ha and rape produces about 800 kg/ha. This means that these energy crops can

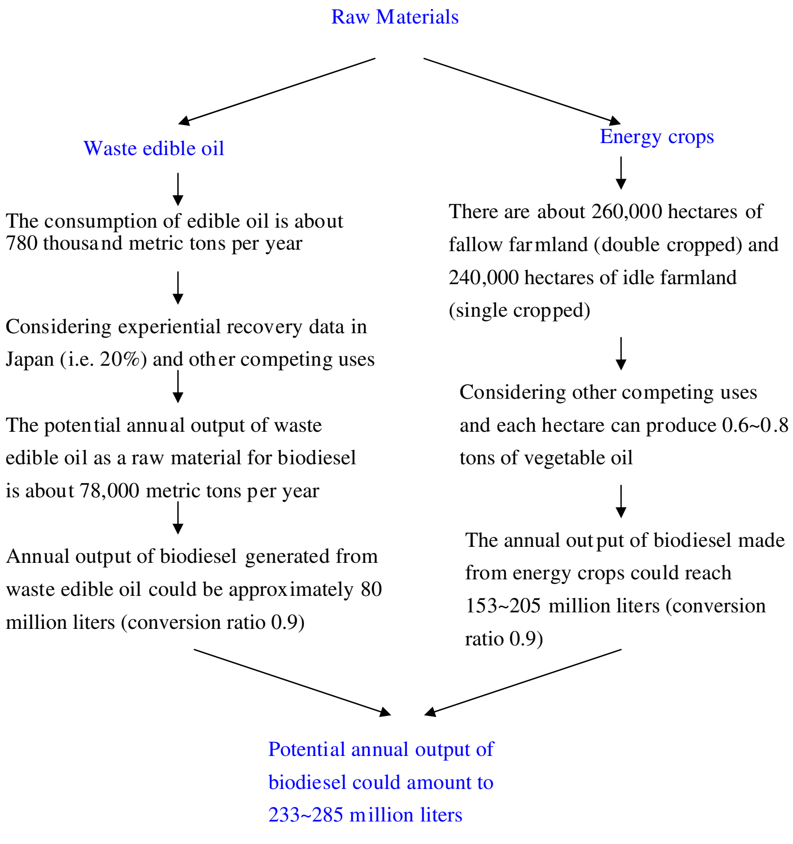


Fig. 2. Potential annual output of biodiesel in Taiwan.

produce 0.6–0.8 metric tons of vegetable oil per hectare [17]. Since the cultivation program uses fallow and idle farmland, planting energy crops is not the only choice. Considering other competing uses, if energy crops are cultivated on just 50% of the fallow and idle farmland, the annual potential output of biodiesel made from energy crops will reach 153–205 million liters. These material sources together with waste edible oil could produce a potential annual output of 233–285 million liters of biodiesel. Under such circumstances, the target of the second National Energy Conference could be achieved. This amount would be equivalent to 3.88–4.75% of the 6000 million liters of fossil diesel Taiwan consumed in 2005 [18]. Adding this biodiesel to the fuel supply would reduce Taiwan's annual carbon dioxide emissions by 764,240–934,800 metric tons. (The coefficient of CO_2 emission reduction is 3.28 metric tons per thousand liters biodiesel according to the Biodiesel Road-Test Program of EPA.)

5. Barriers to the adoption of biodiesel

Preliminary assessments show that the target of the second National Energy Conference could be achieved. However, some barriers hinder biodiesel development in practice.

Among these barriers, a stable supply of raw materials and the high cost of biodiesel are two key problems in Taiwan. These barriers are as follows.

5.1. Raw material

5.1.1. Waste edible oil

Preliminary estimates indicate that the annual output of biodiesel made from waste edible oil could reach 80 million liters per year, but the amount of waste edible oil recovered yearly through known channels is about 30 million liters at present [12]. The flow of other waste edible oils is not known clearly, and the recycling rate must be improved.

5.1.2. Energy crops

Energy crops have not yet been cultivated on a large scale in Taiwan. The estimated output values of biodiesel made from energy crops are based on foreign data [16], and the establishment of local database is still on going.

5.2. Cost

Table 2 shows the unit cost and price of biodiesel [12]. The unit cost of producing biodiesel with waste edible oil and imported palm oil is NT$ 24/liter and NT$ 23/liter, respectively. The unit cost using cultivated sunflower and soybean reaches NT$ 75/liter and NT$ 98/liter, respectively, in Taiwan. Considering by-product (oil seed) revenue and profit margins, the price of biodiesel ranges between NT$ 29/liter and NT$ 64/liter, which is higher than that of fossil diesel (NT$ 22.3/liter, the price on October 25, 2006). The result shows that the present price of biodiesel compared to fossil diesel is still uncompetitive due to high cost of its raw materials.

5.3. Distribution channels

At present, there is no biodiesel gas station and a biodiesel distribution channel needs to be established.

Table 2
The unit cost and price of biodiesel in Taiwan (unit: NT$/liter biodiesel) [12]

Cost items	Feedstock			
	Waste edible oil	Cultivated sunflower	Cultivated soybean	Imported palm oil
Raw material cost	18	63	80	17
Oil pressing cost	0	6	12	0
Transesterification cost	6	6	6	6
Unit cost of biodiesel	24	75	98	23
Revenue of by-products (oil seed)	0	−17	−51	0
Profit margin	6	6	6	6
Price of biodiesel	30	64	53	29

Note: (1) 1 NT$ is equivalent to 0.03 US$; (2) the revenue of by-products only includes oil seed here.

5.4. Public acceptance

Currently, road tests and engine exhaust emissions tests are being conducted on the garbage trucks and public sector buses only. Test results for other kinds of vehicles are not available. Public acceptance needs to be enhanced. Information dissemination and education on biodiesel should be facilitated.

5.5. Legislation

The Chinese National Standards (CNS) of biodiesel are being discussed by the Bureau of Metrology, Standards and Inspection (BSMI). In addition, policy incentives should be legislated as soon as possible.

To conclude, at present, the development of biodiesel in Taiwan is in the initial stage; related subsidiary mechanisms (such as tax exemption, investment subsidies) have not been introduced. The relatively cheap fossil diesel price in Taiwan and high raw material cost of biodiesel make it difficult to promote biodiesel without governmental support.

6. Policy measures to promote biodiesel

It is important that related policy measures are in place for the promotion of biodiesel in Taiwan. Fig. 3 summarizes the related policy measures. The key policy measures are

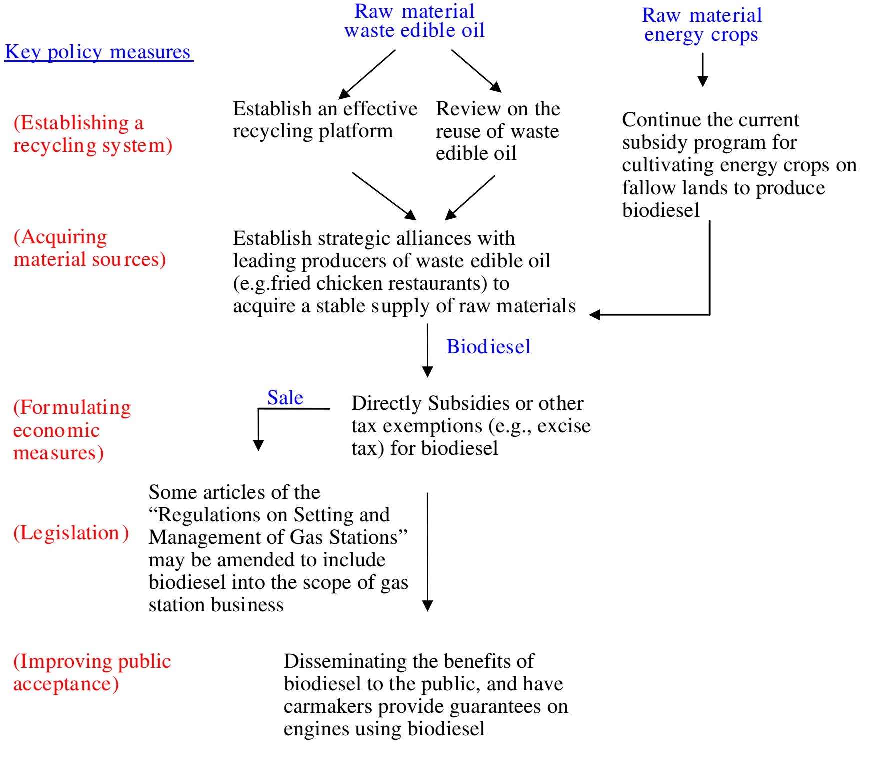


Fig. 3. Future framework for promoting biodiesel in Taiwan.

acquiring material sources, establishing a recycling system, defining economic and legal measures, and improving public acceptance.

6.1. Raw material

6.1.1. Waste edible oil

Biodiesel producers can establish strategic alliances with leading producers of waste edible oil (e.g., fried chicken restaurants) to acquire a stable material supply and improve corporate image. Meanwhile, effective recycling platforms should be established to control and improve the flow and recycling rate of waste edible oil. In the current Industrial Development Bureau classification and management methods of industrial waste recycling, there are basic management specifications on recycling waste edible oil (industrial waste code: 27). The Recycling Industry Website of the Industrial Development Bureau has established a waste recycling registration system [19]. However, free declaration is adopted at present, and no compulsive requirements have been made. In the future, the government could control the output and distribution of waste edible oil by putting this registration system into effect through inspection and dissemination. In addition, if the Environmental Protection Administration takes active measures to establish a waste edible oil recycling system, this will substantially increase the waste edible oil recycling rate.

6.1.2. Energy crops

The Council of Agriculture should continue its current subsidy program to encourage farmers to plant energy crops on fallow farmland. It is also necessary to establish localized production cost data. The Council of Agriculture is planting sunflowers, rape, and soybeans on 30 ha in Northern, Central, and Southern Taiwan, respectively. This will help estimate localized production costs. Finally, the oil yield of local energy crops, harvesting techniques, oil pressing, and biodiesel processing should be developed and improved to reduce production costs.

6.2. Price

The government may provide necessary subsidies for biodiesel in the promotion period, and exempt the related taxes on biodiesel (e.g., excise tax) to improve its market competitiveness.

6.3. Distribution channels

Articles of the "Regulations on Setting and Management of Gas Stations" may be amended at the proper time to include biodiesel in the scope of gas station business. According to recent "Green Energy Development Plan" proposed by Ministry of Economic Affairs, two counties will be chosen where the gas stations will begin to make biodiesel available to consumers in 2007.

6.4. Public acceptance

The mass media could also play an important role in communicating the benefits of biodiesel to the public and thereby raising general awareness and acceptance. Educational

activities should be held to inform the public that biodiesel is an environment-friendly fuel; carmakers could also provide relevant guarantees on engines using biodiesel to increase consumer confidence. According to "Green Energy Development Plan", biodiesel will first be used by public buses in certain cities and counties at the end of 2006.

6.5. Legislation

Rapid passage of the Chinese National Standards on biodiesel and legislating related policy incentives are crucial factors to expanding the biodiesel market in Taiwan.

The promotion of biodiesel also requires the cooperation of different ministries. It will require concerted efforts from the country's energy, agricultural, environmental protection, and industrial sectors. To effectively put the above policy measures into practice, it is necessary to establish inter-ministry coordination mechanisms to facilitate the promotion of biodiesel. In addition, "Biodiesel Road-Test Program" and "Green Energy Development Plan" implemented by the government are expected to continue so as to promote the utilization of biodiesel gradually.

7. Conclusion

Biodiesel is a non-toxic, biodegradable fuel. It can be used directly in diesel engine with minor or no adjustments. Substituting fossil diesel with biodiesel can reduce air emissions, increase domestic supply energy, and create new markets for farmers. From a public health viewpoint, generating biodiesel from waste edible oil can prevent waste edible oil being recycled or re-used in restaurants. Further, generating biodiesel from energy crops cultivated on polluted farmlands also provides a solution for re-using polluted farmlands.

Some biodiesel promotion programs have already been implemented in Taiwan. For example, ITRI's Energy and Environment Research Laboratories have established Taiwan's first biodiesel demonstration system through cooperation with the Taiwan NJC Corporation; the Environmental Protection Administration has provided subsidies for 13 counties and cities to carry out a "Biodiesel Road-Test Program" on garbage trucks; and the Council of Agriculture is planting energy crops such as sunflowers, rape, and soybeans on 90 ha in Northern, Central, and Southern Taiwan and subsidizing farmers to cultivate energy crops on fallow farmland. The Changhua County Government actively promotes soybeans cultivation on cadmium-contaminated farmlands and cooperates with Taiwan NJC Corporation to produce biodiesel. In addition, related national standards on biodiesel are being legislated.

Biodiesel development in Taiwan is still in its initial stage. Preliminary assessments show that the annual output of biodiesel generated from waste edible oil could reach approximately 80 million liters. To achieve the target value of 100 million liters, energy crops must be cultivated or raw materials should be imported to produce biodiesel. With these material sources, the potential annual output of biodiesel could reach 233–285 million liters, meaning that the goal of the second National Energy Conference could be achieved. However, there are some barriers hampering biodiesel development in practice. To further promote biodiesel in the future, key policy measures such as acquiring material sources, establishing a recycling system, defining economic and legal measures, and improving public acceptance must still be addressed. In addition, "Biodiesel Road-Test Program" and "Green Energy Development Plan" implemented by the government are

expected to continue so as to promote biodiesel gradually. To effectively put the above policy measures in practice, it is necessary to set up inter-ministry coordination mechanisms to actively promote the utilization of biodiesel in Taiwan.

Acknowledgment

The authors would like to thank Dr. H.T. Lee (Deputy Director, New Energy Technology Division, Energy & Environment Research Laboratories, Industrial Technology Research Institute) for his valuable comments on the earlier version of this paper.

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